TECHNOLOGY NEEDS/OPPORTUNITIES STATEMENT

UNDERSTAND, QUANTIFY AND DEVELOP DESCRIPTIONS OF BIOGEOCHEMICAL REACTIONS AND INTERACTIONS BETWEEN CONTAMINANTS OF CONCERN AND AQUIFER SEDIMENTS TO DESCRIBE BIOCHEMICAL REACTIVE TRANSPORT

Identification No.: RL-SS34
Date: September 2001

Program: Environmental Restoration
OPS Office/Site: Richland Operations Office/Hanford Site
Operable Unit(s): Broad need potentially applicable to multiple operable units.
PBS No.: RL-SS04 (RL-VZ01)
Waste Stream: Groundwater (Disposition Map Designation: ER-10 [technical risk score 5] and ER-18 [technical risk score 5])
TSD Title: N/A
Waste Management Unit (if applicable): N/A
Facility: N/A

***Priority Rating*:**

This entry addresses the "Accelerated Cleanup: Paths to Closure (ACPC)" priority:

_X_ 1. Critical to the success of the ACPC
____ 2. Provides substantial benefit to ACPC projects (e.g., moderate to high lifecycle cost savings or risk reduction, increased likelihood of compliance, increased assurance to avoid schedule delays)
____ 3. Provides opportunities for significant, but lower cost savings or risk reduction, and may reduce uncertainty in ACPC project success.

***Need Title*:** Understand, Quantify and Develop Descriptions of Biogeochemical Reactions and Interactions Between Contaminants of Concern and Aquifer Sediments to Describe Biochemical Reactive Transport

Need/Opportunity Category: Technology Need

***Need Description*:** This need addresses specific technical gaps identified in the scope of the Groundwater/Vadose Zone Integration Project (Integration Project) at the Hanford Site and is written as an "integrated" need. The Integration Project is focused on providing the scientific and technical basis to ensure that Hanford Site decisions, including decisions related to long-term stewardship, are defensible and possess an integrated perspective for the protection of water resources, the Columbia River, river-dependent life, and users of the Columbia River resources. As such, this "integrated" need has both applied S&T components that are interrelated in addressing the specified technical gap. Individual efforts applied to resolve the technical gaps described in this need may address all or part of the components identified for this need. Where

a specific technology need can be defined separately from an “integrated” need, a specific technology need statement has been written and is included elsewhere in the Hanford Site STCG Subsurface Contamination Needs (e.g., RL-SS25: Improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation).

This need focuses on the reactions and interactions between contaminants and aquifer sediments. The primary technical gap is an insufficient understanding of these processes at Hanford in terms of quantifying and parameterizing the processes for use in reactive transport modeling and to determine appropriate conceptual models. Biogeochemical reactions may result in either enhanced contaminant mobility, degradation (natural attenuation), or fixation in the unconfined aquifer. An understanding of these fundamental processes is needed to predict the long-term behavior of contaminants as they enter the unconfined aquifer and during transport along the groundwater flow path to the river. The need for reactive transport modeling has been pointed out by several recent peer reviews at the Hanford Site, one for the RPP vadose zone contamination issue and more recently for the Hanford site-wide groundwater model. Specific needs to address this technical gap include the following.

- Mobility of transuranic (TRU) radionuclides (especially neptunium-237) in the groundwater, including the potential for complexation with DNAPL and the potential for colloid formation and transport.

- Information is needed to determine and quantify reactions such as biodegradation and interactions with aquifer sediments that impact the fate of dissolved DNAPL such as CCl_4 in the groundwater.

- Techniques are needed to measure chemical, physical, and biological reactions and interactions in the aquifer and parameterize these measurements for use in models. Additionally, appropriate model formulations of these reactions and interactions are needed such that they can be incorporated into fate and transport models.

- Information is needed to understand the relationship between geochemical reactions and hydrogeological properties that affect transport in the aquifer.
- Descriptive kinetic and thermodynamic information for reactions and interactions in the aquifer based on key biogeochemical and hydrochemical reactions that control the fate and transport of contaminants in the groundwater are needed. Specific information needed includes the following. Determination of the speciation and complexation of contaminants of interest in the aquifer (Science Need RL-SS23-S). Information is needed to understand the reactions that will affect the binding of contaminants in solution on secondary mineral surfaces, and on primary phases (Science Need RL-SS24-S). The reaction rates and the key reaction steps that control the speed with which a contaminant changes chemical form (e.g., speciation, complexation) and/or interacts with the surfaces of secondary minerals need to be quantified (Science Need RL-SS26-S). An understanding of the effect of coupled abiotic and biogeochemical reactions for which independent rates of reaction are known on contaminant form (e.g.

speciation/complexation) is needed (Science Need RL-SS27-S). As is relevant to the fate and transport of carbon tetrachloride, information is needed to understand and quantify the rates of degradation reactions of naturally occurring organic matter and synthetic organic compounds that supply energy to subsurface biological consortia that participate in dechlorination of halogenated solvents (Science Need RL-SS32-S).

- Information is needed determine the chemical form and mobility of DNAPLs such as chlorinated solvents in the aquifer (Science Need RL-SS25-S).

- Information is needed to understand which secondary minerals form as colloids in groundwater, the importance of biosorption, the nature of the chemical interactions between contaminants of interest and the surfaces of inorganic and organic colloids, and the affect of colloids on contaminant transport at Hanford (Science Need RL-SS28-S).

- Model formulations are needed for the chemistry and physics that describe the dispersal and longevity of subsurface contaminant plumes for site conditions, contaminant chemistry and reactivity, and hydraulic properties at Hanford (Science Need RL-SS31-S).

- Techniques are needed to use readily-measured chemical analogues (similar group, charge, ionic size) to contaminants of interest to assess the behavior of difficult-to-measure contaminants in the Hanford subsurface (Science Need RL-SS35-S).

- Evaluation of naturally occurring microbial communities in the groundwater and their impact on radionuclide and metal mobility is needed to understand current and predict future migration of contaminants.

The use of site-specific media (appropriate Hanford Site groundwater and sediments) are essential for all laboratory testing involved in acquiring the above information. Also, care must be taken to acquire “undisturbed” sediment samples to avoid altering the chemical reactivity of the natural materials.

Schedule Requirements:

Earliest Date Required: 8/1/99

Latest Date Required: 9/30/05

The Integration Project S&T roadmap (DOE/RL-98-48, 2000) indicates the information that is required over the next 6 years to meet the objectives of the Integration Project. Information associated with reactions and interactions in the aquifer is needed in the FY 2000 to FY 2004 timeframe to meet these objectives.

***Problem Description*:** This need falls under the Groundwater Technical Element within the S&T Endeavor. The Groundwater Technical Element is intended to address and resolve scientific issues related to understanding the role of groundwater in the overall migration of contaminants from the Hanford Site. The objective of the Groundwater Technical Element is to enhance protection of the Columbia River and its environs by 1) determining the existing distributions of contaminants with particular emphasis on 3D distribution especially at the interfaces with the vadose zone and the river and 2) enhancing the understanding of geological, chemical, geochemical, and hydrologic controls for future movement of contaminants. Understanding the flux and dynamics of vadose-capillary fringe-groundwater contaminant transfer and plume migration in three dimensions is critical to reconstructing vadose zone transport. On a larger scale, transport processes in groundwater control migration to extraction wells or surface water bodies (e.g., the Columbia River), define future risk scenarios, and affect the potential for optimized cleanup. An implicit goal of this research is to provide sufficient knowledge and data and identify existing and new S&T for input to DOE's decision-making process for Hanford cleanup.

This technical element provides the information, analytic capabilities, and understanding required for improving the technical basis for assessments of Hanford Site impacts to groundwater resources and the Columbia River. Groundwater represents an important portion of the potential exposure path and is the link between the source/vadose system and receptors at a well or the river. The technical scope of the groundwater element complements that of the vadose zone element by extending the characterization work into the saturated sediments under the Hanford Site. The saturated zone includes the capillary fringe, the unconfined aquifer, aquitards, and uppermost confined aquifers. The technical scope of the groundwater element also compliments that of the river element by providing input to contaminant flux to the river and other interactions between the groundwater and Columbia River. Major topics include (1) the distribution of contamination within the saturated sediments; (2) the hydrology, geology, geochemistry, and microbiology of the saturated zone; (3) groundwater flow and transport of contamination; and (4) numerical models that depict the movement of water and contaminants.

Benefit to the Project Baseline of Filling Need: Information gained by filling this need will provide an appropriate description of important reactions and interactions related to contaminant transport. Thus, there will be less uncertainty in the technical basis used for decisions. The activity that this need supports will be used to support development of site-specific assessments as well as the SAC as part of the GW/VZ Integration Project. Successful completion of these activities is required to meet the objectives of the Integration Project and the related elements of the Paths to Closure.

***Functional Performance Requirements*:** The techniques applied or information that is obtained must describe and quantify reactions and interactions between contaminants of concern and aquifer sediments such that the information can be applied toward the conceptual models, fate and transport numerical models, and system assessment capabilities that are being developed as part of the Integration Project. The information must provide a better understanding of current conditions, and the ability to assess potential future conditions for near- and long-term scenarios.

Work Breakdown Structure (WBS) No. : 1.4.03.4.4 ***TIP No.:***

Relevant PBS Milestone: PBS-MC-042

***Justification For Need*:**

Technical: There is an insufficient understanding of these processes at Hanford in terms of quantifying and parameterizing the processes for use in reactive transport modeling and to determine appropriate conceptual models. Biogeochemical reactions may result in either enhanced contaminant mobility, degradation (natural attenuation), or fixation in the unconfined aquifer. An understanding of these fundamental processes is needed to predict the long-term behavior of contaminants as they enter the unconfined aquifer and during transport along the groundwater flow path to the river for both site-specific assessments as well as to provide support for parameters used in the SAC.

Regulatory: Information obtained by addressing this need will provide an improved technical basis for making site regulatory decisions and therefore reduce the uncertainty associated with the basis for these decisions.

Environmental Safety & Health: This need addresses broad sitewide technical issues and, as such, crosscuts multiple applications that each may have specific environmental safety and health issues.

Potential Life-Cycle Cost Savings of Need (in $000s) and Cost Savings Explanation: The estimated life-cycle cost savings associated with filling this need is $200M. This estimate is based on an assumed savings of 5% of the total Hanford remediation life-cycle cost of >$5B. Estimated savings are due to information and data gained by filling this need that supports decisions for cost effective remediation and long-term stewardship.

Cultural/Stakeholder Concerns: This technology need supports the resolution of cultural and stakeholder concerns as expressed by the CRCIA Team in “Columbia River Comprehensive Impact Assessment, Part II: Requirements for a Columbia River Comprehensive Impact Assessment” (DOE 1998).

Other: None.

Current Baseline Technology: N/A

End-User: Richland Environmental Restoration Project

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DOE End-User/Representative Point-of-Contact: John G. Morse, DOE-RL, (509) 376-0057

Reference:

United States Department of Energy. 1998. Columbia River Comprehensive Impact Assessment, Part II; Requirements for a Columbia River Comprehensive Impact Assessment. DOE/RL-96-16. United States Department of Energy, Richland, Washington.

United States Department of Energy. 2000. Groundwater/Vadose Zone Integration Project Science and Technology Summary Description. DOE/RL-98-48, Vol. III, Rev. 1, U.S. Department of Energy, Richland, Washington.